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A new freshwater shrimp species of the genus *Caridina* (Crustacea, Decapoda, Atyidae) from Quang Ninh province, Northeast Vietnam

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Abstract

A new species of atyid freshwater shrimps from Quang Ninh province, Northeast Vietnam is described. *Caridina baitulong* **sp. nov.** can be distinguished from its congeners by a suite of morphological characters such as the rostrum reaching to the middle or end of the second segment of antennular peduncle, stylocerite reaching to the end or sometimes slightly overreaching distal end of basal segment of antennular peduncle, endopod of male first pleopod sub-rectangular, appendix interna of male second pleopod extending about 0.7 times length of appendix masculina. Molecular phylogenetic analysis of the mitochondrial cytochrome oxidae subunit (COI) and 16S ribosomal RNA (16S) genes also clearly support the distinctiveness of the new species from all other examined species, while also suggesting high intra-specific divergence.

Key Words

Caridina, distribution, diversity, endemism, Freshwater fauna, taxonomy

Introduction

Freshwater shrimps of the family Atyidae have been studied in Vietnam from the beginning of the 20th century up to the present (Bouvier 1904, 1919, 1925; Dang 1967, 1975; Dang et al. 1980; Cai et al. 1999; Nguyen 1999; Li and Liang 2002; Dang and Do 2007; Do and Dang 2010; Dang and Ho 2012; Do et al. 2020; Do et al. 2021a, b, c; Phan et al. 2021). Until now, a total of 25 atyid species belonging to the three genera *Caridina* H. Milne Edwards, 1837, *Neocaridina* Kubo, 1938, and *Atyopsis* Chace, 1983, have been recorded from Vietnam (Do et al. 2020; Do et al. 2021a, b).

In recent surveys around North Vietnam, we collected some specimens of *Caridina*, which were examined and compared with other species from around regions. We identified this species as being new to science based on a suite of morphological characters and supported by genetic data from the mitochondrial cytochrome oxidase subunit I (COI) and 16S ribosomal RNA (16S) genes.

Materials and methods

Specimens of the new species were collected by hand nets from streams in Quang Ninh Province, mainly in Bai Tu Long bay, North Vietnam (Suppl. material 1). After collection, living specimens were photographed with a Nikon D5600 Digital Camera to record the coloration and then preserved in 70–95% ethanol. In the laboratory, the specimens were dissected, observed and body parts were photographed under a Nikon SMZ18 stereo microscope. The drawings were then processed with Adobe Photoshop CS5 and Adobe Illustrator CS2 graphics software. The material examined was deposited at the Institute Biology (IB), Viet Nam Academy of Science and Technolo-

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gy, Hanoi, Viet Nam, and at the crustacean wet collection at the Museum für Naturkunde (ZMB), Berlin, Germany. The holotype is deposited in the country of origin. The abbreviation cl is used for carapace length, measured from the postorbital margin to the posterior median margin of the carapace in mm. The rostral formula used in this study is defined as (number of dorsal teeth on the carapace posterior to the orbital margin + number of dorsal teeth on the rostrum anterior to the orbital margin/number of ventral teeth of the rostrum).

For the molecular analyses, DNA was purified from about 2 mm^3 of abdominal muscle tissue either with QiaCube or a Qiagen BioSprint with the Plant Kit (but lysis with 10 ml Qiagen Proteinase K (20 mg/ml) added) according to the manufacturer's instructions. Polymerase chain reaction (PCR) was used to amplify two mitochondrial gene fragments, a ~590 bp region of the 16S ribosomal RNA gene (16S) using primers 16S-F-Car and 16S-R-Car1 and a 861 bp fragment of the Cytochrome Oxidase subunit I gene (COI) using primers COI-F-Car and COI-R-Car (von Rintelen et al. 2007). Fragments of the mitochondrial 16S, and COI, sequenced using primers 16S-F-Car and 16S-R-Car1 (16S), and COI-F-Car and COI-R-Car (COI) (von Rintelen et al. 2007), or, for COI only, COI-F-Car and COI-R-H16mod3 (1087 bp fragment extending COI-F-Car/COI-R-Car fragment at 3' end; 5' CAAYKATCT-GCCATTTTAGA), sometimes in combination with COI-F-Car and COI-R-int (458 bp fragment at 5' end of COI-F-Car/COI-R-Car fragment; 5' GCAA-TAAT-TATAGTTGCTGA). In the latter case, sequencing was done using COI-R-int and COI-R-H16mod3.

PCR was performed in 25 µl volumes containing 1x Taq buffer, 1.5 mM MgCl2, 200 µM each dNTP, 1 U Taq polymerase, ca. 50–100 ng DNA and ddH2O. After an initial denaturation step of 3 min at 94 °C, cycling conditions were 35 cycles at 94 °C for 35 s, 45 °C (COI) or 50 °C (16S) for 60 s, and 72 °C for 180 s (COI) or 90 s (16S), with a final elongation step of 5 min at 72 °C. The same primers were used in PCR and sequencing. PCR products were sent to Macrogen Europe for purification and cycle sequencing of both strands of each gene.

Contigs of forward and reverse strands were assembled using GENEIOUS PRIME (v. 2025.0.3) and corrected by eye. Sequences were aligned by eye (COI) and with MAFFT (16S) (Katoh and Standley 2013) as implemented in GENEIOUS. In addition to the sequences generated for this study, sequences of most other Vietnamese atyid species and additional sequences of three species from outside Vietnam published by Do et al. (2020, 2021a, b, 2025) plus five outgroup species from the genera *Atya*, *Atyopsis* and *Potimirim* have been included in the analysis. The resulting alignments had a length of 821 bp (COI) and 545 bp (16S). To determine the best substitution model for Bayesian inference analyses (see below), hierarchical likelihood ratio tests were carried out with jModelTest (Posada 2008) on both sequence sets (24 models tested). Based on the Akaike Information Criterion, the GTR + I + G model was chosen for both COI and 16S, which were subsequently analyzed concatenated. All new sequences have been deposited in GenBank (see Table 1).

Phylogenetic trees were reconstructed by Bayesian inference (Huelsenbeck and Ronquist 2001) using MRBAYES 3.2.6 (Ronquist et al. 2012). The MCMC-MC-algorithm was run with four independent chains for 10,000,000 generations, samplefreq = 500, and burnin = 25%. Maximum likelihood (ML) analyses were run with IQ-TREE (Nguyen et al. 2015) using W-IQ-TREE (Trifinopoulos et al. 2016), and branch support was obtained through the implemented ultrafast bootstrap (10,000 replicates) (Hoang et al. 2018). BI and ML analyses were run using two gene partitions with the model specified above. Genetic distances were calculated using MEGA 11 (Stecher et al. 2020; Tamura et al. 2021).

Results

Taxonomy

Family Atyidae De Haan, 1849
Genus *Caridina* H. Milne Edwards, 1837

***Caridina baitulong* sp. nov.**

https://zoobank.org/3F65EBED-9216-4BEA-B2AC-CAF838625E28

Figs 1–3

Examined material. ***Holotype*:** • 1 male, cl 3.8 mm, IB-FS 011, Vietnam, Quang Ninh Province, Van Don District, Ba Mun Island, a small stream, 21°4'27.57"N, 107°35'33.8159"E, coll. Do Van Tu, 9 May 2018.

***Paratypes*:** 14 males, cl 3.1–3.9 mm, 4 females, cl 3.9–4.4 mm, 76 additional specimens, ZMB 31583, same data as holotype; • 1 male, cl 3.8 mm, 1 female cl. 4.0 mm, IB-FS 012, same locality as IB-FS 011 and ZMB 31583, coll. Do Van Tu, 20 March 2023; • 1 male, cl 3.5, 1 female, cl 4.1 mm, 105 additional specimens, ZMB 31578, Vietnam, Quang Ninh Province, Van Don District, Ba Mun Island, a small stream, 21°4'33.36"N 107°35'30.666"E, coll. Do Van Tu, 9 May 2018; • 1 male, cl 3.6 mm, 22 additional specimens, ZMB 31586, Quang Ninh Province, Mong Cai District, a stream near the road to the border, 21°36'38.304"N 107°44'3.75"E, coll. Do Van Tu, 24 January 2018, coll. Do Van Tu, 8 May 2018; • 1 male, cl 3.9 mm, 1 female cl. 4.1, 105 additional specimens, ZMB 31582, Quang Ninh Province, Van Don District, Cai Lim Island, a small stream, 21°6'18.6059"N 107°34'17.568"E, coll. Do Van Tu, 8 May 2018; • 1 male cl. 3.9 mm, 1 female cl. 4.1 mm, 5 additional specimens, ZMB 29650, Vietnam, Quang Ninh Province, Cam Pha City, a small stream, 21°08'12.3"N 107°16'15.7"E, coll. Do Van Tu, 2007; • 1 male, cl 3.7 mm, 1 female cl. 4.0 mm, 3 additional specimens, ZMB 29651, same locality as ZMB 29650, coll. Do Van Tu, 3 January 2011.

Comparative material. *Caridina clinata* Cai, Nguyen & Ng, 1999: • 2 males, cl 3.1 and 3.6 mm, ovigerous female,

Table 1. Specimens of atyid taxa used for DNA sequencing.

Species	Museum acc. no. (DNA lab code)	Locality	GenBank acc. no. COI	GenBank acc. no. 16S	Source
Atya gabonensis	MfN (DNA Crust 437)	West Africa (pet trade)	EF489962	EF489989	Page et al. 2008
Atya scabra	MfN (DNA Crust 510)	Panama (pet trade)	EF489964	EF489985	Page et al. 2008
Atyopsis moluccensis	MfN (DNA Crust 222)	Indo Pacific region (pet shop in Germany)	DQ681246	DQ681281	Page et al. 2007
Atyopsis spinipes	ZMB 29779 (779)	Indonesia, Aceh, Aceh Selatan	PV644212	PV642627	Do et al. 2025
Caridina baitulong	ZMB 29650-1 (1738)	Vietnam, Quang Ninh, Cam Pha	PV799323	PV799961	This study
	ZMB 29650-2 (1739)	Vietnam, Quang Ninh, Van Don	PV799324	PV799962	
	ZMB 29651-1 (1740)	Vietnam, Quang Ninh, Mong Cai	PV799325	PV799963	
	ZMB 29651-2 (1741)		PV799326	PV799964	
	ZMB 31578-1 (2286)		PV799327	PV799965	
	ZMB 31578-2 (2287)		PV799328	PV799966	
	ZMB 31582-1 (2294)		PV799971	PV799967	
	ZMB 31582-2 (2295)			PV799968	
	ZMB 31583-1 (2296)			PV799969	
	ZMB 31583-2 (2297)			PV799970	
	ZMB 31586-1 (2302)			PV799971	
	ZMB 31586-2 (2303)			PV799960	
Caridina caobangensis	ZMB 30255 (1942)	Vietnam, Cao Bang, Ha Quang, Truong Ha, Pac Bo	MT526826	MT526809	Do et al. 2020
Caridina cantonensis	ZMB 32183 (669)	China, Zuhai	KP168758	KP168717	Klotz and von Rintelen 2014
Caridina clinata	ZMB 31777 (2511)	Vietnam, Ninh Binh, Cuc Phuong	MT526827	MT526810	Do et al. 2020
Caridina cucphuongensis	ZMB 30234 (2093)	Vietnam, Ninh Binh, Cuc Phuong	PV644218	PV642634	Do et al. 2025
	ZMB 31744 (2503)		MT526828	MT526811	Do et al. 2020
Caridina gracilipes	ZMB 30231 (2089)	Vietnam, Hai Phong, Thuy Nguyen	MT526829	MT526812	Do et al. 2020
Caridina haivanensis	ZMB 30304-1 (2042)	Vietnam, Thua Thien-Hue, Hai Van	PV644215	PV642631	Do et al. 2025
	ZMB 30304-2 (2043)	Vietnam, Thua Thien-Hue, Hai Van	PV644216	PV642632	
Caridina lanceifrons	ZMB 29638 (1954)	Vietnam, Hoa Binh, Da Bac	MT526831	MT526814	Do et al. 2020
Caridina macrophora	ZMB 30263 (1958)	Vietnam, Hai Phong, Thuy Nguyen	MT526832	MT52681	Do et al. 2020
Caridina namdat	ZMB 30341-3 (2540)	Vietnam, Bac Kan, Cho Moi, Tan Son, Nam Dat	MZ484397	MZ484401	Do et al. 2021b
	ZMB 30341-4 (2541)		MZ484398	MZ484402	
	ZMB 30342 (2543)		MZ484399	MZ484403	
Caridina ngocson	ZMB 30276-1 (1984)	Viet Nam, Hoa Binh, Lac Son, Ngoc Son	PV644213	PV642628	Do et al. 2025
	ZMB 30276-2 (1985)		PV644214	PV642629	
Caridina nguyeni	ZMB 30280 (1993)	Vietnam, Cao Bang, Ha Quang, Truong Ha, Pac Bo	MT526833	MT526816	Do et al. 2020
Caridina pacbo	ZMB 30295 (2023)	Vietnam, Cao Bang, Ha Quang, Truong Ha, Pac Bo	MT526835	MW525213	Do et al. 2020
Caridina peninsularis	ZMB 29341 (391)	Malaysia, Sarawak, Matan	PV644211	MN399187	Do et al. 2025
Caridina pseudoserrata	ZMB 30343 (2544)	Vietnam, Cao Bang, Quang Yen, Tu Do	MT52683	MT526818	Do et al. 2020
Caridina rubropunctata	ZMB 30314 (2061)	Vietnam, Thai Nguyen, Dong Hy, Van Lang	MT526838	MT526819	Do et al. 2020
Caridina serrata	ZMB 30306 (2047)	Vietnam, Quang Nam, Cu Lao Cham Island	PV644217	PV642633	Do et al. 2025
	ZMB 32189 (671)	China, Hong Kong, Hong Kong Island	KP168722	KP168793	Klotz and von Rintelen 2014
Caridina tamkim	ZMB 32923 (3556)	Vietnam, Nguyen Binh District, Tam Kim	PV644225	PV642642	Do et al. 2025
	ZMB 32924-1 (3553)	Vietnam, Cao Bang, Nguyen Binh, Tam Kim	PV644224	PV642641	
	ZMB 32924-2 (3555)	Vietnam, Cao Bang, Nguyen Binh	PV644223	PV642640	
	ZMB 33788 (3549)		PV644222	PV642639	
	ZMB 33814 (3627)		PV644226	PV642643	
Caridina tanson	ZMB 32979-1 (3752)	Vietnam, Phu Tho, Tan Son, Dong Son	PV644229	PV642646	Do et al. 2025
	ZMB 32979-2 (3753)		PV644230	PV642647	
Caridina thachlam	ZMB 30338 (2533)	Vietnam, Thanh Hoa, Thach Thanh, Thach Lam	MW505997	MW505991	Do et al. 2021a
	ZMB 31773 (2529)	Vietnam, Ninh Binh, Nho Quan, Cuc Phuong	MW505999	MW505993	
	ZMB 31781 (2519)		MW506000	MW505994	
Caridina tricincta	ZMB 30360-1 (2572)	Vietnam, Ha Giang, Bac Me, Lac Nong	MT526839	MT526822	Do et al. 2020
	ZMB 30360-2 (2573)		MT526840	MT526823	
	ZMB 30363-1 (2576)		MT526841	MT526824	
Caridina xuanlien	ZMB 32944-1 (3529)	Vietnam, Thanh Hoa, Thuong Xuan, Van Xuan	PV644220	PV642637	Do et al. 2025
	ZMB 32944-2 (3530)	Vietnam, Thanh Hoa, Thuong Xuan, Yen Nhan	PV644221	PV642638	
	ZMB 32948-1 (3665)		PV644227	PV642644	
	ZMB 32948-2 (3668)		PV644228	PV642645	
Neocaridina palmata	ZMB 30256 (1944)	Vietnam, Cao Bang, Ha Quang, Truong Ha, Pac Ma	MT526843	MT526825	Do et al. 2020
Paracaridina zijinica	ZMB 32180 (663)	China, Heyuan	KP168798	KP168782	Klotz and von Rintelen 2014
Potimirim potimirim	ZMB 29476 (431)	Panama, Bocas del Toro	EF489975	FN995386	von Rintelen et al. 2012

cl 3.7 mm, ZMB 30664, Vietnam, Ninh Binh, a small stream in Cuc Phuong National Park, 20°19'11.118"N 105°37'42.168"E, coll. Thomas von Rintelen & Do Van Tu, 4 March 2017. *Caridina pacbo* Do, von Rintelen & Dang, 2020: • male, cl 4.2 mm, IB–FS 003 (Holotype), Vietnam, Cao Bang province, Ha Quang District, Truong

Ha Commune, Pac Bo Village, small stream in Khuoi Nam, 22°59'1.7"N 106°02'31.2"E, coll. Do Van Tu, 25 May 2017. *Caridina tricincta* Do, von Rintelen & Dang, 2020: • male, cl 5.3 mm, IB–FS 001 (Holotype), Vietnam, Tuyen Quang Province, Na Hang District, Khau Tinh Commune, 22°26'42.1"N 105°23'09.1"E, coll. Nguyen Anh Tuan, 11 December 2012. *Caridina serrata* Stimpson, 1860: • 10 males, cl 3.1–4.7, 5 females, cl 4.0–4.6, ZMB 30306, Vietnam, Quang Nam Province, Hoi An City, Cu Lao Cham Island, a small stream running into the reservoir, 15°56'34.9"N 108°31'22.7"E, coll. Pham The Cuong, 10 May 2017.

Cephalothorax and cephalic appendages. Carapace length 3.1–4.4 mm (median 3.6 mm, n = 20). Rostrum slender, straight, sometimes downward-curving, reaching to end of second segment of antennular peduncle, 0.41–0.59 (median 0.47) times as long as carapace, rostral formula 3–4+6–10/2–4 (Fig. 1A). Suborbital angle acute, completely fused with antennal spine; pterygostomian margin rounded, slightly produced forward (Fig. 2A). Eyes well developed with globular cornea, anterior end reaching to 0.7 times length of basal segment of antennular peduncle (Fig. 1A). Antennular peduncle 0.5–0.7 (median 0.58) times as long as carapace; basal segment 1.62–2.38 (median 1.86) times as long as second segment, second segment 1.02–2.17 (median 1.37) times as long as third segment (Fig. 1B). Stylocerite reaching to end of basal segment of antennular peduncle (Fig. 1B). Scaphocerite ovate, reaching beyond distal end of antennular peduncle, 2.16–4.89 (median 3.7) times as long as wide (Figs 1A, C).

Abdominal somites, telson and uropods. Sixth abdominal somite 0.36–0.51 (median 0.44) times length of carapace, 1.1–1.84 (median 1.49) times as long as fifth abdominal somite, 0.62–1.06 (median 0.79) times length of telson. Telson length 2.51–3.53 (median 3.26) times as long as proximal wide, distal margin triangular, terminating in a short median projection, with 5–6 pairs of dorsal spiniform setae and one pair of dorso-subdistal spiniform setae; distal end with 3–5 pairs of spiniform setae, lateral pair longer than intermediate pairs (Figs. 1D, E). Preanal carina low, slightly bent backwards, with few setae, lacking a spine (Fig. 1F). Uropodal diaeresis with 16–22 (median 20) movable spiniform setae, outermost shorter than lateral angle (Fig. 1G).

Mouthparts and branchiae. Incisor process of mandible ending in one row of 6–7 irregular teeth, molar process truncated (Fig. 1H). Lower lacinia of maxillula broadly rounded, upper lacinia elongated, with a number of distinct teeth and setae on inner margin, palp stout with few simple setae at tip (Fig. 1I). Upper endites of maxilla subdivided, palp short, scaphognathite tapering posteriorly, with numerous long, curved setae at posterior margin (Fig. 1J). Distal end of palp of first maxilliped triangular, with a short projection; flagellum of the exopod very elongated, endopod high, reaching 0.7 times length of flagellum of exopod (Figs 1K, L). Podobranch of second maxilliped incompletely reduced, with few finger-like projections (Fig. 1M). Third maxilliped reaching to end of antennular peduncle, ending in single terminal claw, exopod reaching 0.6 times length of penultimate segment; ultimate slightly shorter than penultimate segment; epipod present on the coxa (Fig. 1N). Branchial formula as typical for genus *Paracaridina* Liang, Guo & Tang, 1999, five pairs of pleurobranchs well developed; two pairs of arthrobranchs on third maxillipeds, with second pair strongly reduced in size; one pair of podobranchs on second maxilliped slightly reduced, arthrobranch on first pereiopod absent (Liang et al. 1999).

Pereiopods. Epipod present on first to fourth pereiopods. First pereiopod short, robust, reaching end of basal segment of antennular peduncle; chela 1.98–2.59 (median 2.21) times as long as wide, 1.05–1.51 (median 1.37) times length of carpus; tips of fingers rounded, without hook; usually dactylus longer than palm, 0.88–1.88 (median 1.2) times as long as palm; carpus excavated strongly anteriorly, 1.37–2.04 (median 1.75) times as long as wide; carpus 0.83–1.36 (median 1.05) times length of merus; merus 1.99–3.29 (median 2.48) times as long as wide, longer than ischium (Fig. 2A). Second pereiopod long, slender, reaching beyond distal end of antennular peduncle; chela 2.4–3.22 (median 2.59) times as long as wide, 0.64–0.85 (median 0.76) times length of carpus; tips of fingers rounded, without hook; dactylus 1.12–2.25 (median 1.55) times as long as palm; carpus 5.0–7.85 (median 5.68) times as long as wide, 1.03–1.34 (median 1.14) times as long as merus; merus 3.91–5.64 (median 4.88) times as long as wide, longer than ischium (Fig. 2B). Third pereiopod slender, reaching beyond distal end of antennular peduncle by its dactylus, terminating in one claw, with five accessory spiniform setae on flexor margin, dactylus 2.05–4.78 (median 3.69) times as long as wide (terminal claw and spiniform setae on flexor margin included), propodus 8.06–11.5 (median 10.43) times as long as wide, 3.35–6.72 (median 3.65) times as long as dactylus; carpus 3.9–6.0 (median 4.75) times as long as wide, 0.49–0.85 (median 0.63) times as long as propodus, 0.34–0.61 (median 0.51) times as long as merus; merus 5.12–8.7 (median 6.56) times as long as wide, bearing 3 strong, movable spiniform setae on posterior margin of outer surface; ischium with one small movable spiniform seta (Figs. 2C, D). Fifth pereiopod slender, reaching to end of third segment of antennular peduncle, dactylus 2.71–5.2 (median 4.14) times as long as wide (terminal claw and spiniform setae on flexor margin included), terminating in one large claw, with 27–34 spiniform setae on flexor margin; propodus 11.3–14.88 (median 12.93) times as long as wide, 3.35–6.45 (median 4.22) times length of dactylus; carpus 3.59–6.29 (median 5.13) times as long as wide, 0.41–0.65 (median 0.48) times as long as propodus, 0.51–0.78 (median 0.6) times as long as merus; merus 5.5–8.29 (median 6.88) times as long as wide, bearing 3 strong, movable spiniform setae on posterior margin of outer surface, ischium without movable spiniform setae (Figs 2E, F).

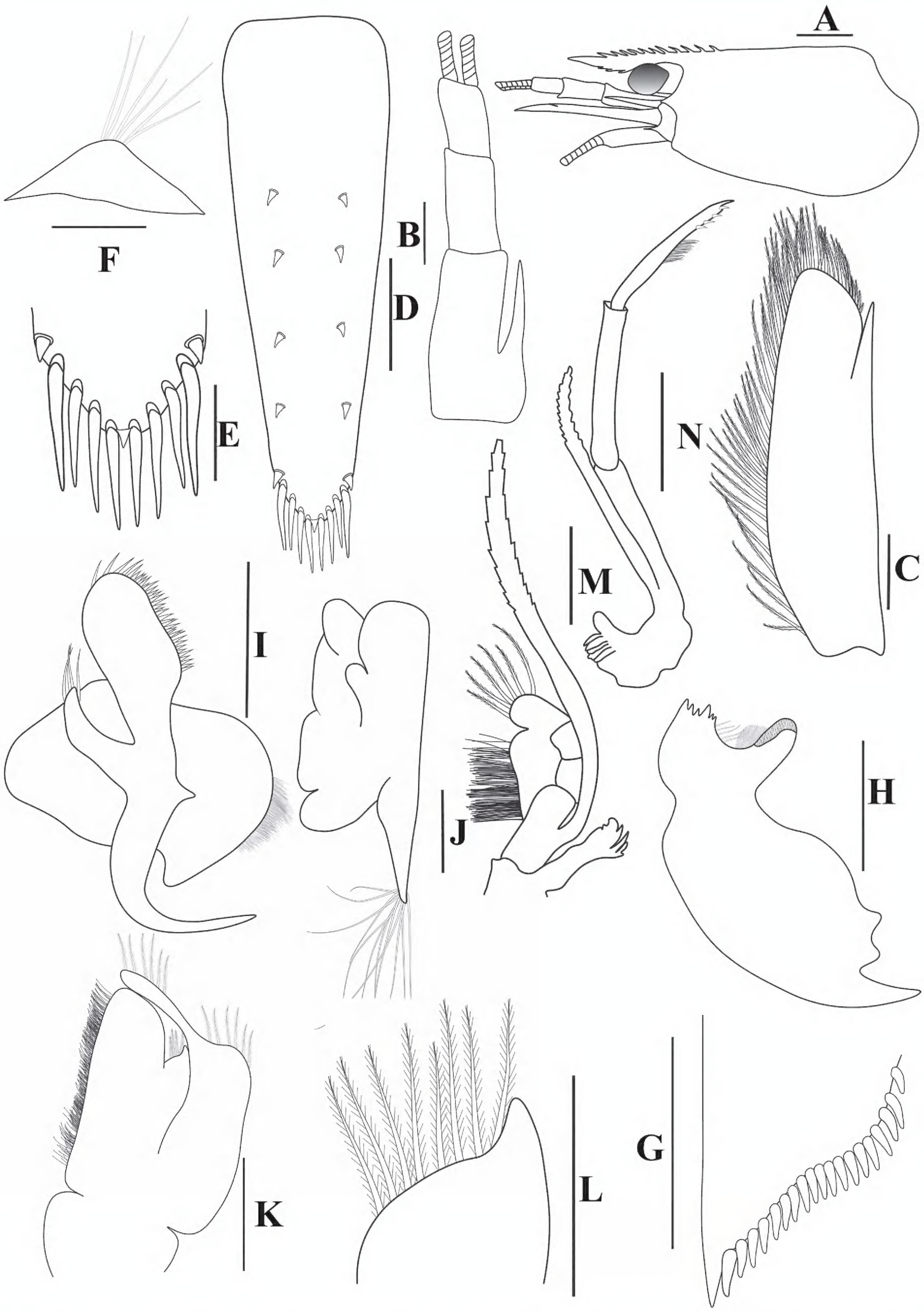

Figure 1. *Caridina baitulong* sp. nov. male paratype, cl 4.6 mm (ZMB 31583). **A.** Cephalothorax and cephalic appendages, lateral view; **B.** Antennular peduncle; **C.** Scaphocerite; **D.** Telson; **E.** Distal portion of telson; **F.** Preanal carina; **G.** Uropodal diaeresis; **H.** Mandible; **I.** Maxillula; **J.** Maxilla; **K.** First maxilliped; **L.** Distal end of palp of first maxilliped; **M.** Second maxilliped; **N.** Third maxilliped. Scale bars: 1 mm (**A**); 0.5 mm (**B–D**); 0.2 mm (**E–J**).

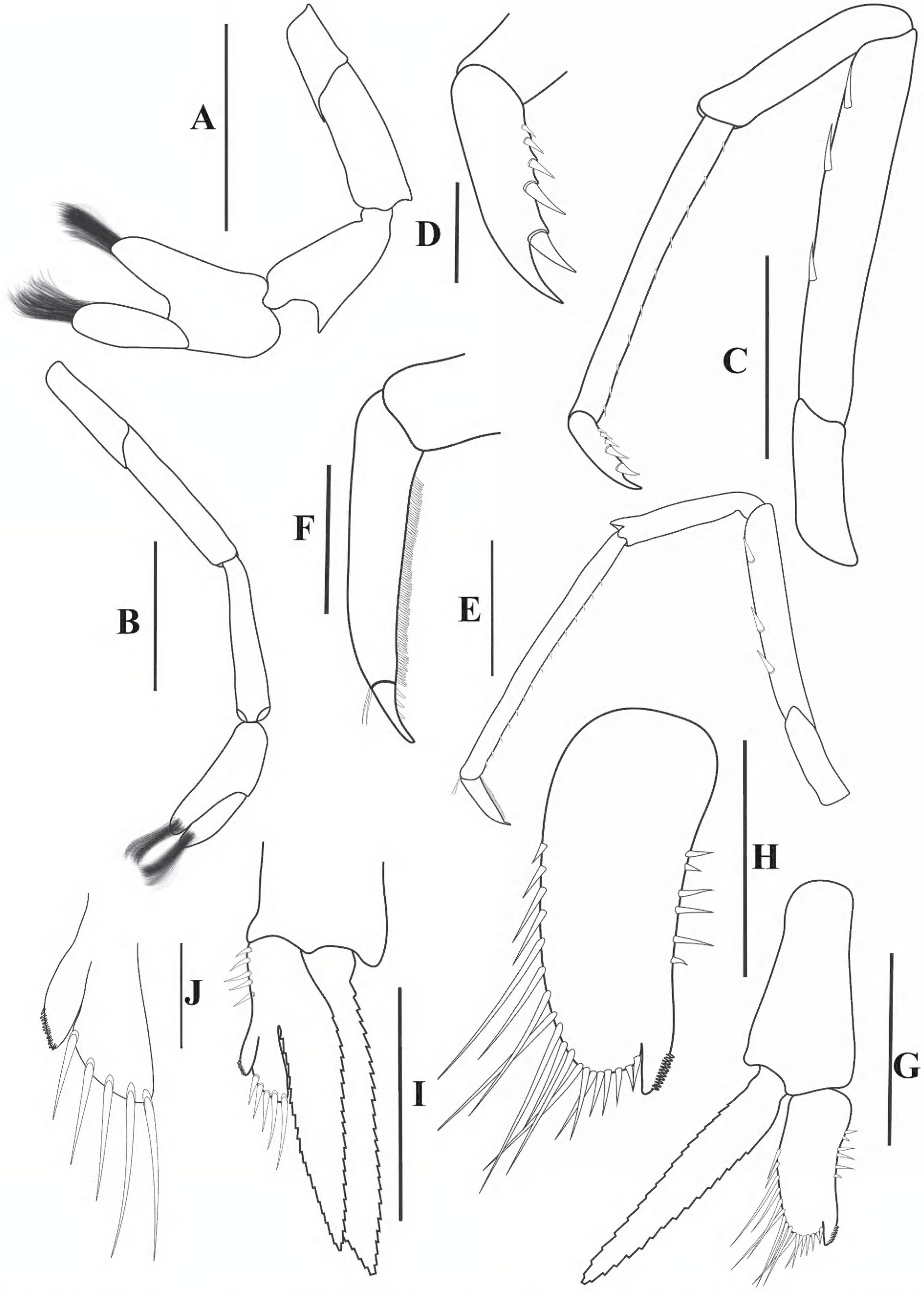

Figure 2. *Caridina baitulong* sp. nov., male paratype, cl 4.6 mm (ZMB 31583). **A.** First pereiopod; **B.** Second pereiopod; **C.** Third pereiopod; **D.** The same, dactylus; **E.** Fifth pereiopod; **F.** The same, dactylus; **G.** Male first pleopod; **H.** Endopod of male first pleopod; **I.** Male second pleopod; **J.** Appendix masculina and interna of male second pleopod. Scale bars: 1 mm (**A, B, C, F, G, I**); 0.2 mm (**D, E, H, J**).

Pleopods. Endopod of male first pleopod extending to 0.55 times exopod, elongated and rectangular in shape, 2.53–2.85 (median 2.7) times as long as proximal width, inner margin concave, outer margin slightly convex, rounded distally, long pappose setae on outer and distal margins, medium-length simple setae on inner margin; with appendix interna exceeding terminal margin of endopod by 0.36 its length (Figs 2G, H). Appendix masculina of male second pleopod stout, reaching to proximal 0.56 times endopod length, 4.44–5.0 (median 4.72) times as long as distal width, thumb-shaped, with some short spiniform setae on outer surface and some long spiniform setae on distal surface; appendix interna at the middle of appendix masculina, narrow, small, extending about 0.7 times length of appendix masculina (Figs 2I, J).

Coloration. The body is slightly yellowish to grey. Some individuals have black spots and stripes of irregular size over the whole body (Figs. 3A, B).

Reproductive biology. Egg size (from n = 5 ovigerous females, eggs with developed eyes) 1.0–1.1 × 0.61–0.62 mm. The carapace length of the smallest ovigerous female is 3.9 mm.

Etymology. The new species is named after the type locality, Bai Tu Long bay. The name is used as a noun in apposition.

Habitat. This new species was found in a stream with mixed sand, gravel, and rock substratum, and clear flowing water from the forest (Fig. 4).

Distribution. Our survey data throughout Vietnam indicate that this species is restricted to Quang Ninh province. The big eggs are also clearly indicative of a landlocked life cycle.

Molecular phylogenetic results. *Caridina baitulong* sp. nov. is well-supported as a distinct lineage (Fig. 5, Suppl. material 2). The species seems to be closest to the *Caridina serrata* species group, but this relationship is not supported. The minimum genetic divergence (p-distance) to any other Vietnamese atyid species is 11.3% (COI; *Paracaridina zijinica*, (reported as *Caridina typus* in Phan et al. 2021, pers. obs.)) and 5.2% (16S;

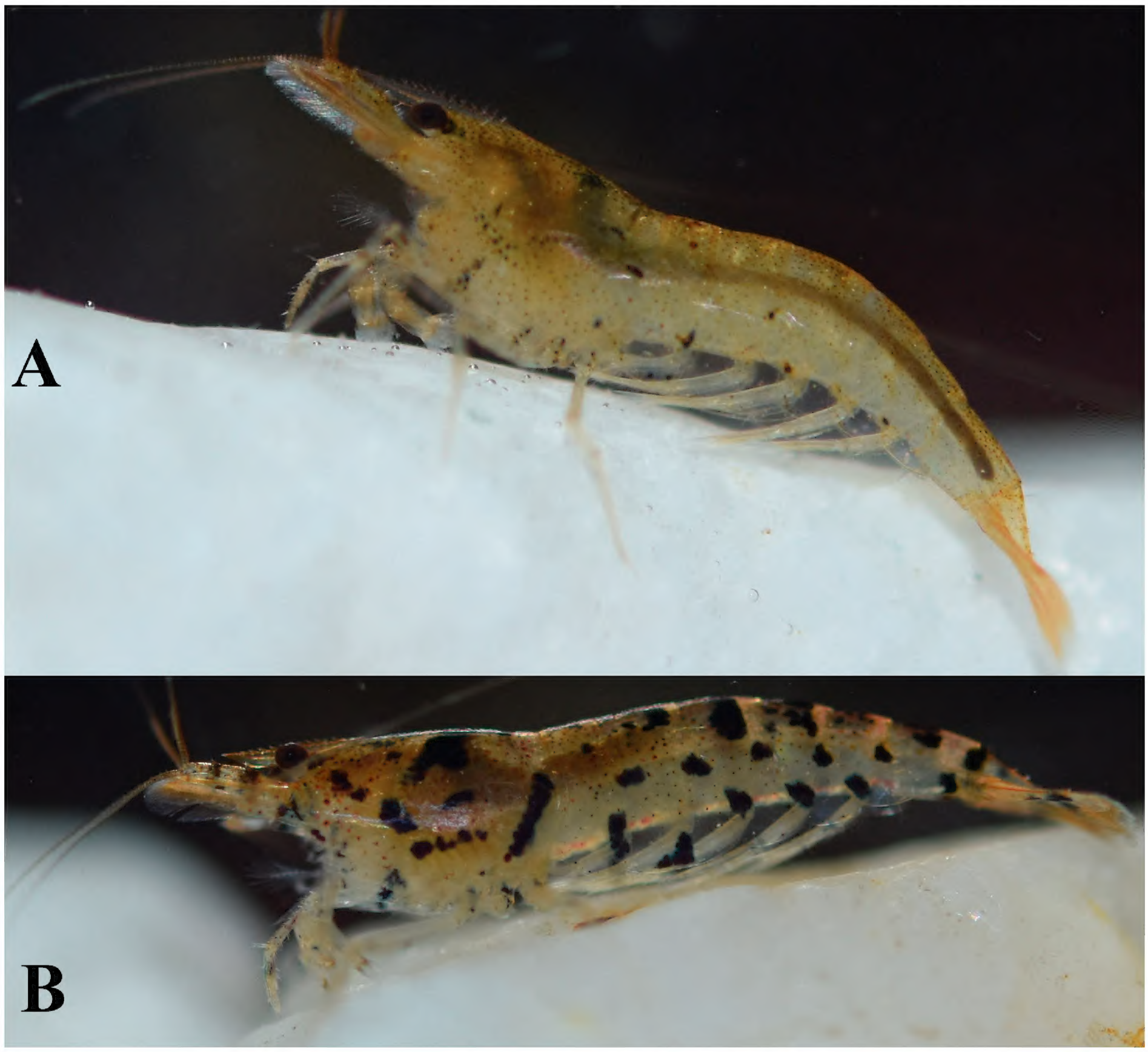

Figure 3. A, B. Live coloration of *Caridina baitulong* sp. nov. paratypes (IB-FS 012), collected in Quang Ninh Province.

Figure 4. Habitat of *Caridina baitulong* sp. nov. in Ba Mun Province.

C. tricincta, *C. thachlam*), respectively. The maximum divergence found within *C. baitulong* sp. nov. is 4.5% (4.3% when using the same dataset as for COI) for 16S and 9.3% for COI.

Remarks. *Caridina baitulong*, new species is characterized by several morphological characters such as short rostrum, reaching to end of second segment of antennular peduncle; rostrum formula 6–10+3–4/2–4; stylocerite reaching to end of basal segment of antennular peduncle; subrectangular endopod of male first pleopod with appendix interna exceeding terminal margin of endopod by 0.36 its length; appendix masculina of male second pleopod stout, reaching to proximal 0.56 times endopod length, thumb-shaped; appendix interna extending about 0.7 times length of appendix masculina.

Caridina baitulong somewhat resembles *C. serrata* Stimpson, 1860, *C. clinata* Cai, Quynh & Ng, 1999, *C. tricincta* Do, von Rintelen & Dang, 2020 and *C. pacbo* Do, von Rintelen & Dang, 2020 by possessing a short rostrum and the shape of endopod of male first pleopod (Stimpson 1857; Cai et al. 1999; Do et al. 2020; Phan et al. 2021). However, *C. cucphuongensis* can be easily distinguished from these species by the characters shown in Table 2.

The large genetic distances found between the sampled populations of *Caridina baitulong* sp. nov. seem remarkable, particularly given the rather restricted distribution area of the species (Suppl. material 2). In land-locked species this is a common pattern (see e.g. de Mazancourt et al. 2023), but the intraspecific genetic distance in *Caridina baitulong* sp. nov. exceeds the minimum genetic distance found among other Vietnamese species of *Caridina* such as *C. cucphuongensis* and *C. namdat*, or *C. clinata* and *C. xuanlien*. There is no universal genetic divergence threshold for species delimitation even in closely related groups of crustaceans (Costa et al. 2007), so this is not necessarily problematic. Despite the large intraspecific variation in the two investigated mtDNA markers, the morphology of the species is quite homogenous across all studied populations and the high genetic distance found within *Caridina baitulong* sp. nov. might simply reflect ancestral mitochondrial polymorphism. It might be speculated that the separation of populations by sea level fluctuations has played a role in shaping this pattern.

Caridina baitulong sp. nov. has the defining character of *Paracaridina* Liang, Guo & Tang, 1999 because of its branchial formula (5 pairs of pleurobranchs well developed; 2 pairs of arthrobranchs on third maxillipeds, with second pair strongly reduced in size; 1 pair of podobranchs on second maxilliped slightly reduced, arthrobranch on first pereiopod absent). However, this character is not unique to *Paracaridina* (von Rintelen et al. 2008) and genetically the new species does not

Table 2. Main differences between *Caridina baitulong* sp. nov. and similar species in Vietnam.

Morphology characteristics	*C. baitulong* sp. nov.	*C. cucphuongensis*	*C. serrata*	*C. clinata*	*C. tricincta*	*C. pacbo*
Rostrum	Reaching to end of second segment of antennular peduncle	Reaching to beginning of second segment of antennular peduncle	Nearly reaching to or slightly reaching beyond end of basal segment of antennular peduncle	Reaching to or slightly exceeding distal margin of basal segment of antennular peduncle	Reaching to middle or slightly falling short of distal end of basal segment of antennular peduncle	Reaching beyond middle or close to end of basal segment of antennular peduncle
Rostrum formula	3–4+6–10/2–4	1–3+5–7/0–2	0–5+5–12/0–6	3–5+13–21/2–5	0–3+0–6/0–5	2–6+5–12/0–3
Stylocerite	Reaching to end of basal segment of antennular peduncle	Reaching to beginning of second segment of antennular peduncle	Reaching to the end of basal segment to middle of second segment of antennular segment.	Not reaching distal margin of basal segment of antennular segment.	Reaching distal end of basal segment of antennular peduncle.	Mostly reaching beyond the end of basal segment, sometimes to the middle of second segment of antennular peduncle.
Endopod of male first pleopod	2.53–2.85 (median 2.7) times as long as proximal width	2.5–2.82 (median 2.8) times as long as proximal width	2.5 times as long as proximal width	2.8 times as long as proximal width	3.0–3.25 (median 3.0) times as long as proximal width	0.86–3.33 (median 3.09) times as long as proximal width
Appendix interna of male second pleopod	Extending about 0.7 times length of appendix masculina	Extending about 0.4 times length of appendix masculina	Extending about 0.3 times length of appendix masculina	Extending about 0.8 times length of appendix masculina	Extending about 0.9 times length of appendix masculina	Extending about 0.6 times length of appendix masculina
Uropodal diaeresis	16–22 (median 20) movable spiniform setae	18–21 (median 20) movable spiniform setae	20–22 movable spiniform setae	14–17 movable spiniform setae	12–18 movable spiniform setae	19–20 movable spiniform setae

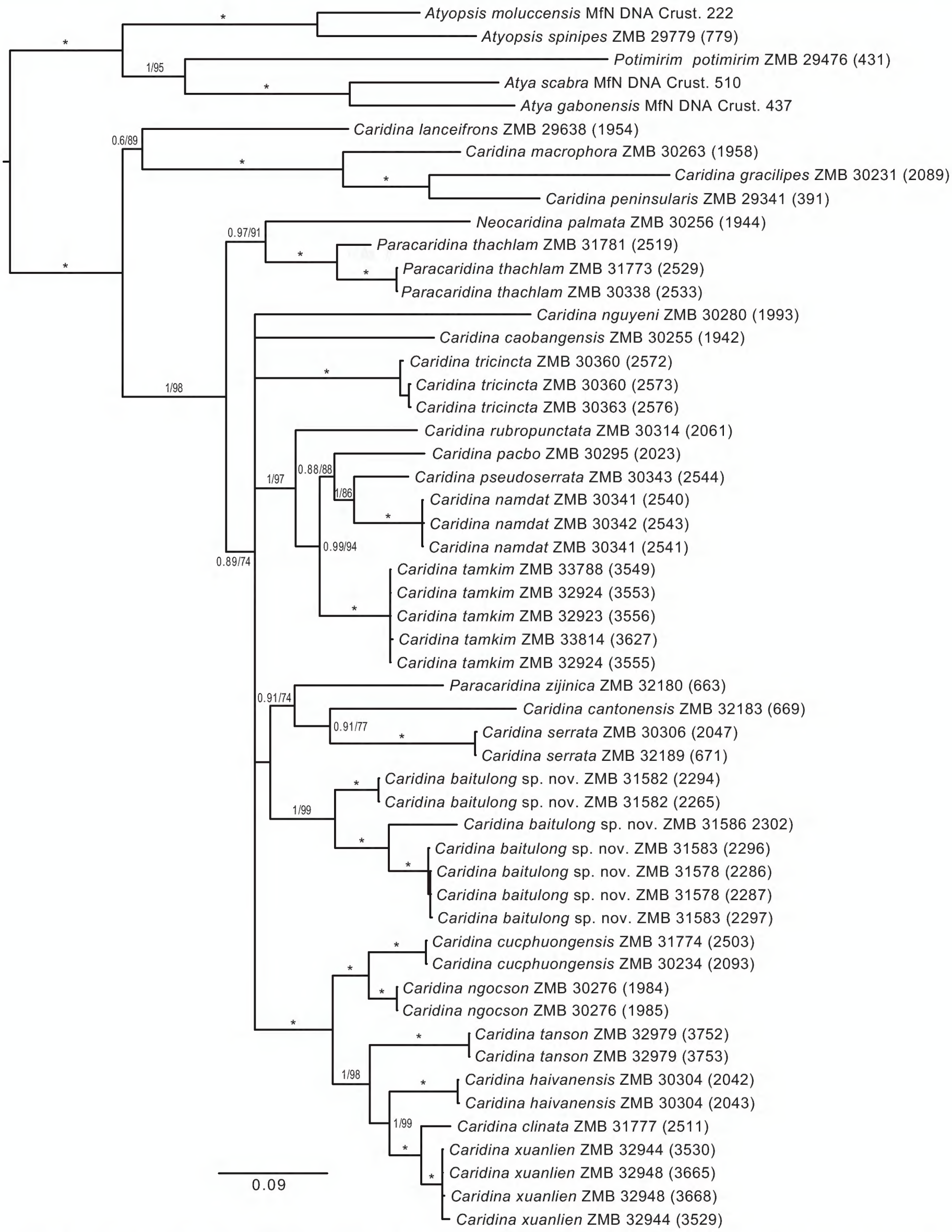
Atyopsis moluccensis MfN DNA Crust. 222
Atyopsis spinipes ZMB 29779 (779)
Potimirim potimirim ZMB 29476 (431)
Atya scabra MfN DNA Crust. 510
Atya gabonensis MfN DNA Crust. 437
Caridina lanceifrons ZMB 29638 (1954)
Caridina macrophora ZMB 30263 (1958)
Caridina gracilipes ZMB 30231 (2089)
Caridina peninsularis ZMB 29341 (391)
Neocaridina palmata ZMB 30256 (1944)
Paracaridina thachlam ZMB 31781 (2519)
Paracaridina thachlam ZMB 31773 (2529)
Paracaridina thachlam ZMB 30338 (2533)
Caridina nguyeni ZMB 30280 (1993)
Caridina caobangensis ZMB 30255 (1942)
Caridina tricincta ZMB 30360 (2572)
Caridina tricincta ZMB 30360 (2573)
Caridina tricincta ZMB 30363 (2576)
Caridina rubropunctata ZMB 30314 (2061)
Caridina pacbo ZMB 30295 (2023)
Caridina pseudoserrata ZMB 30343 (2544)
Caridina namdat ZMB 30341 (2540)
Caridina namdat ZMB 30342 (2543)
Caridina namdat ZMB 30341 (2541)
Caridina tamkim ZMB 33788 (3549)
Caridina tamkim ZMB 32924 (3553)
Caridina tamkim ZMB 32923 (3556)
Caridina tamkim ZMB 33814 (3627)
Caridina tamkim ZMB 32924 (3555)
Paracaridina zijinica ZMB 32180 (663)
Caridina cantonensis ZMB 32183 (669)
Caridina serrata ZMB 30306 (2047)
Caridina serrata ZMB 32189 (671)
Caridina baitulong sp. nov. ZMB 31582 (2294)
Caridina baitulong sp. nov. ZMB 31582 (2265)
Caridina baitulong sp. nov. ZMB 31586 2302)
Caridina baitulong sp. nov. ZMB 31583 (2296)
Caridina baitulong sp. nov. ZMB 31578 (2286)
Caridina baitulong sp. nov. ZMB 31578 (2287)
Caridina baitulong sp. nov. ZMB 31583 (2297)
Caridina cucphuongensis ZMB 31774 (2503)
Caridina cucphuongensis ZMB 30234 (2093)
Caridina ngocson ZMB 30276 (1984)
Caridina ngocson ZMB 30276 (1985)
Caridina tanson ZMB 32979 (3752)
Caridina tanson ZMB 32979 (3753)
Caridina haivanensis ZMB 30304 (2042)
Caridina haivanensis ZMB 30304 (2043)
Caridina clinata ZMB 31777 (2511)
Caridina xuanlien ZMB 32944 (3530)
Caridina xuanlien ZMB 32948 (3665)
Caridina xuanlien ZMB 32948 (3668)
Caridina xuanlien ZMB 32944 (3529)
1/95
0.6/89
0.97/91
1/98
1/97
0.88/88
1/86
0.99/94
0.89/74
0.91/74
0.91/77
1/99
1/98
1/99
0.09

Figure 5. Bayesian Inference phylogram showing the relationships of *Caridina baitulong* sp. nov. to other Vietnamese atyids, based on the analysis of two mitochondrial gene fragments. Numbers on branches show Bayesian posterior probabilities (>0.7) and ML bootstrap values (>70). An asterisk indicates nodes with full support (1/100) in both analyses. The scale bar indicates the substitution rate. Numbers in brackets give the DNA accession number at MfN (MfN DNA Crust). See Table 1 for information on the sequenced specimens.

cluster with *Paracaridina* but – albeit with weak support – rather with *Neocaridina*. We have thus chosen the conservative approach of tentatively assigning it to *Caridina* given the clear need of a taxonomic revision at the genus level for these three genera (see Do et al. 2021b).

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Supplementary material 1

Collection sites of *Caridina baitulong* sp. nov.

Authors: Le Hung Anh, Thomas von Rintelen, Phan Thi Yen, Do Van Tu

Data type: jpg

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Link: https://doi.org/10.3897/zse.101.155668.suppl1

Supplementary material 2

Phylogenetic relationships of populations of *Caridina baitulong* sp. nov. reconstructed by BI analyses of 16S gene fragments

Authors: Le Hung Anh, Thomas von Rintelen, Phan Thi Yen, Do Van Tu

Data type: png

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